AUTOMATED SYSTEM FOR CONTROL, MONITORING AND DIAGNOSTICS OF WINDMILL

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ABSTRACT

The aim of this article is to summarize the most common faults in electric generators and to specify the priority liable to control, monitoring and diagnostics. It describes the structure of an automated system for control, monitoring and diagnostics of a wind power plant, selection of sensors and the places of their location.

Keywords: Windmill, Automated system, Diagnostics, Monitoring, Control.

1. INTRODUCTION

Windmills (wind farms) are unique technology and the rapid development of wind energetic is remarkable. In terms of continuous improvement of technology, good economic condition and specific expertise of the wind resource, wind farms can reach to 5% of the global electricity production.

Proper management of the wind power plant and proper site selection for the construction are crucial for their efficiency and return the investments. For places in Bulgaria where wind farms are built, the time of returning the investments ranges from 5 to 14 years. It is also necessary to provide optimal parameters of the wind turbines in all operating conditions and to maintain the technical capability of the system at the highest level to avoid unintended damage that could lead to suspension of their work and financial losses.

The construction of system for control, monitoring and diagnostics of wind farm is associated with lower costs than repairing and preventing them. The diagnostics system performs earlier detection of mechanical, electrical and thermal faults and failures.

The aim of this study is to explore the possibilities for creation of automated wound control system for control, monitoring and diagnostics (ASCMD) of the wind plant.

To achieve it the following problems have to be solved:

- Summarizing the most common faults in electric generators;
- Specifying the priority subsystems liable to control, monitoring and diagnostics;
- Offering ASCMD structure of the wind farm, choosing sensors and the places of their location.

2. FAILURES IN WIND TURBINES

To build an effective ASCMD it is appropriate to address the most common forms of damage which may occur as well as their manifestation characteristics of the basic element and component of the wind turbine construction. The means and methods of controlling their condition are also of great importance.

The most common faults in the generator are summarized in Table 1.

TABLE 1 *The most common faults in the generator*

Type of failure	Reason
Breakthrough of the winding to the corpus	Short circuit or overload (overvoltage).
Failure of the sliding bearings	Overheating of the bearings is due to: insufficient supply of oil or contaminated with dust or particles oil; improper alignment of the bearings, pressure in the rings caused by axial displacement of the rotor or insufficient clearance between the top surfaces of the bearings shell and the soles of the shaft, oil leakage towards the internal part of the machine.
Wearing out of the isolation	Loosening of strengthening roads and wires in the channels, local partial discharge, accelerated aging, local overheating of the winding, weakening of the strengthened spliced and vibration in them, lowering its reliability, reducing its electrical resistance.
Fault in the rolling bearings	Overheating due to wearing out, dust, lack of axial clearances etc. Oil leakage from the bearing, unusual noise from the bearings along with temperature increase, disruption of the isolation leading to their heating, worn-out working surface also leads to temperature raise and increased level of vibration.
Vibrations	They are caused by imbalance in the rotating parts, mechanical failures, unbalanced rotating parts, low oil temperature in the bearings (which should not be lower than 30^0C at the time of entry and 35^0-40^0 during work), resonance of the generator or its separate parts; short circuit or interruption in the wound rotor, large unevenness in the air gap between the rotor and the stator.
Abnormal noise during work	Winding breakdowns, asymmetrical (skewed) arrangement of the windings groups (when parallel sections are available), unfavorable conditions for air intake to cool the generator, flaws in the rolling bearings, axial displacement and vibration of the rotor.
Local heating of the stator package	Fault in the sheet insulation and weakening of the stator package, causing vibration of the damaged sheets from the package and subsequent heating of these spots; due to the displacement of some segments of the stator package there is a possibility of modification of the package shapes and the subsequent scratch of the rotors.
Rotor vibration during work	Cracks on the surface of the rotor; breach stiffening rings and wedges of the rotor winding.
Modification in the air gaps form	Modification in the shape of the air gap is caused by the broken alignment between the rotor and the stator packages; the appearance of asymmetry in the currents of the parallel sections of the winding; a possibility of scratching the rotor during work, which inevitably leads to destruction.

The main nodes of the generator structure and the parameters which must be monitored are presented in Table 2.

TABLE 2 *Main nodes of the structure and parameters for monitoring*

Element	Form of fault occurrence and the cause of it	Type and location of the sensors
Stator package	Increased vibrations which are the result of the weakened stator package fixture	Sensors placed on the frame
	Local overheating due to the sheet isolation failure	Thermal sensors placed on the active part of the package or thermo-vision camera, thanks to the thermo sensitive special holdings applied where the so called “critical points” occur.
Stator winding	Increased heating of the coil pressure	Thermal sensors or thermo-vision camera to control the thermal state of the coil.
	Control of the state of isolation for detecting the following defects in the winding: weakened channel stabilization; damage in the insulation backing (caused by its extended use).	Partial discharge sensors (PDS). The signal coming from the PDS enters the sensors which are located underneath the wedge channel.
Air gap	Radial fluctuation of the stator, uneven expansion of the stator when heated, dynamic and negative changes in the steadiness of the operating modes and the beating of the shaft.	System for optical control; capacitive sensors located in the stator and the rotor.
Bearings	Unbalance of the rotor; shaft misalignment; uneven air gap; cracks in the rotor; resonance vibrations etc.; defects in the seals.	System for vibration analysis, sensors or indirectly by measuring the temperature of the cooling oil.

3. COMPILATION OF AN AUTOMATED SYSTEM FOR CONTROL, MONITORING AND DIAGNOSTICS FOR A WIND POWER PLANT

Automated system for control, monitoring and diagnostics (ASCMD) of the generator must observe the temperature, electrical and mechanical parameters and alert if there is excess in their limits. The system contains a controller that stores measured data and compares them with regime parameters.

The system includes a set of temperature, current and voltage sensors, which monitor the condition of the stator and the rotor controller and the control panel.

If any damage occurs in the bars of the stator winding, it is detected by partial discharges in the isolation. PDS shall is ascertained by radio – frequency sensors located on the axis of the poles and capacitive sensors in the stator channels.

In the air gap the magnetic field is measured by three Hall sensors, allowing it to detect a short circuit between coils. Vibration sensors are used for detection of any displacements of the channel wedges and the strengthening ring or any vibrations of the stator package. The temperature of the air gap and the condition of the bearings are also controlled by them.

Mathematical support enables: processing and transmitting the signal from the sensors by selecting the data base, implementation of continuous monitoring and analysis in on – line mode and carrying out special test.

Towards the ASCMD the following requirements are demanded:

- To obtain information about the energy, downtime, operating time;
- To detect fault and failures and to alert them;
- To find the location and cause of the damage

ASCMD consists of the subsystems:

3.1. Subsystem I – Control and Data collection

This subsystem monitors quantitative and qualitative indicators of the energy produced by the algorithm and software from (Heraud, Nedelchev and Koeva, 2013) , (Nedelchev, Heraud and Koeva, 2013), the data is saved in the controller of the wind plant. The collected data is recorded every 10 minutes and includes:

- Active power and standard deviation in the 10 – minute interval;
- Changes in wind speed in this internal (measured by anemometers);
- Temperature of the bearings in the gearbox;
- Temperature of the lubricant oil in the gearbox;
- Temperature of the stator windings of the generator;
- Temperature of the bearings of the generator;
- Power factor;
- Reactive power
- Current in their separate;
- Temperature in the cabin.

3.2. Subsystem II – Monitoring the current operational status and diagnostics

This system includes two areas – monitoring and diagnostics that are considered together because of their relationship and similar technical support. Their converters are identical and have the same inputs, but with different functions and output data. The process of diagnostics is automatically activated immediately after the initial malfunction of the monitoring subsystem is indicated. After spectral analysis of the data the exact location and nature of the fault is identified.

Algorithm for monitoring the output power

The relationship between wind speed ϑ and the active power of the generator *P* gives information about the condition of the rotor. To process this information, measurements every 5 minutes for ϑ and *P*, and for every 3000 measurements are necessary to be made, the following formula is applied:

$$\overline{v_W} = \frac{\sum_{i=1}^{3000} v_{Wi}}{3000};$$

$$\bar{P} = \frac{\sum_{i=1}^{3000} P_i}{3000},$$

Where: $\overline{v_W}$ and $\bar{P}$ – the average value of the wind speed and the active power, for a 5 minutes regular interval, respectively.

In order to estimate the overall technical conditions of the rotor, the data is classified and analyzed. Only variations are taken into consideration as a prerequisite for any damage. The data is sorted (when there is a change in wind speed 0,5 m/s), after that the mean deviation for each data series is being estimated and then the curve for each series is determinate. The sooner this analysis is performed, the better-the system will gives warning about possible deviation at an earlier stage. A similar curve for WT 600 kW is shown in Fig.1.

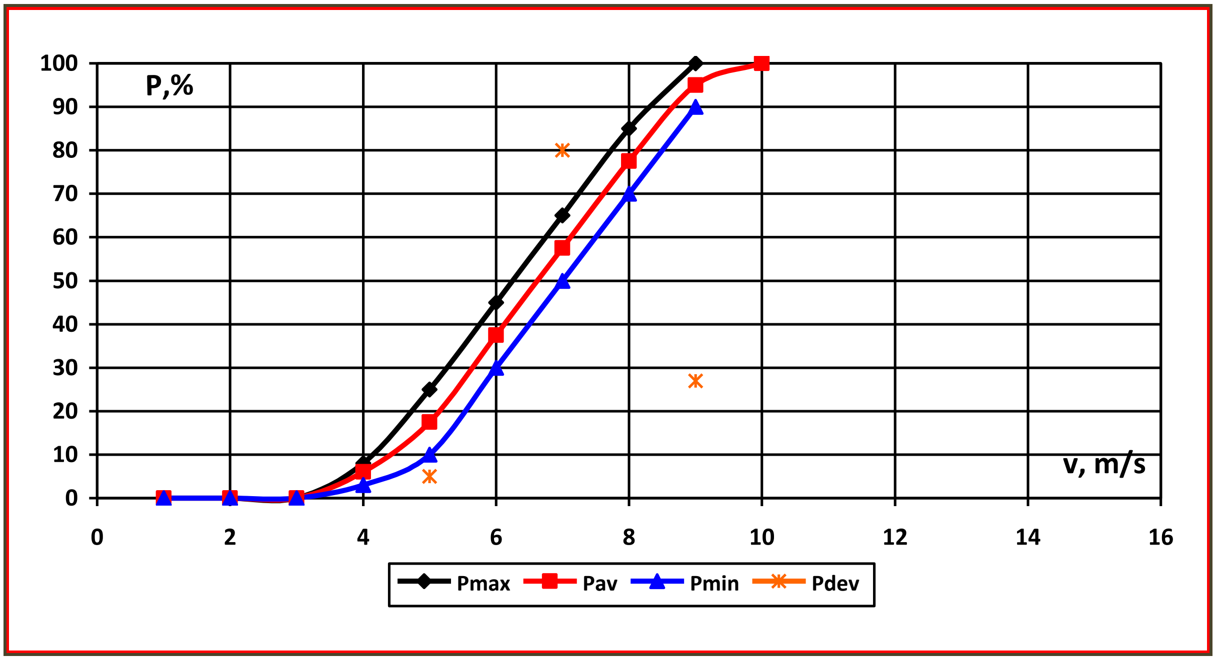

FIGURE 1. *Dependence of the wind power plant on wind speed*

Figure 1 shows the power curve set by the factory (P_{av}); the variance of the output power (P_{dev}) is beyond P_{max} and P_{min}, Therefore a fault should be indicated. All recorded data for the output power should fall within the specified limits.

To avoid false signals a threshold criteria is used – three consecutive signals with a preset duration. This means that if there are four successive extreme values, the signal will be considered as valid and a fast system response will be needed.

In conclusion the following summary can be made:

- Early fault detection is particularly important for distant wind farms, where logistic costs are very high and also for regions where the necessary cranes and other equipment for maintenance is lacking. In such cases it is advisable to implement an ASCMD.
- With the implementation of ASCMD the energy output increases, because sudden failures are avoided; the costs of maintenance and repair is reduced.
- In the presence of ASCMD productivity improves if diagnostics are made, immediate repair actions aren`t necessary. They are taken in a period of low wind intensity when the wind farm is off.

4. CONCLUSIONS

1. The introducing of ASCMD costs far less than repairmen and prevention of wind farm during the life span.
2. Early detection of mechanical, electrical and thermal damage prevents the occurrence of expensive faults and shut downs of the wind farms. Thus, the necessary measures for the

recovery can be planned in time and the plant can be repaired while it`s off because of insufficient wind speed.

3. Early detection of failures is essential for distance wind farms where maintenance costs are very high.

4. With the installation of ASCMD the electricity production increases, thanks to the prevention of sudden failures.

5. The right choice of priority items liable to control, monitoring and diagnostics, as well as the number and location of the deployment of the sensors is the most important part of creating an effective and functional ASCMD.

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